Supporting Information

We consider four hypothesized population models for sandhill cranes of the Rocky Mountain Population using available empirical population-level estimates of vital rates. We define them using population projection matrices (PPM). For all PPM, we used a birth-pulse, post-breeding stage-structured model. Parameters are defined as such: S_1 is juvenile survival, S_i is survival between ages i and $i+1$, and F is per capita fecundity. To make fecundity apply to those individuals in the terminal class that reach the breeding area, we scale fecundity by partial year terminal survival.

$$PPM1 = \begin{pmatrix} 0 & 0 & 0 & 0 & F \\ S_1 & 0 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 & 0 \\ 0 & 0 & S_3 & 0 & 0 \\ 0 & 0 & 0 & S_4 & S_5 \end{pmatrix}$$

where F $= \mathit{PropBreeders} \times \mathit{brood} \times S_5^{8/12}/2$

$\mathit{PropBreeders} = 0.20$ from Drewien, R.C., pers. comm. and Case and Sanders 2009

$\mathit{brood} = 1.23$ from Drewien (2011).

$$PPM2 = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & F \\ S_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & S_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & S_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & S_5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & S_6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & S_7 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & S_8 & S_9 \end{pmatrix}$$

where F $= PropBreeders \times brood \times S_9^{8/12}/2$

$PropBreeders = 0.20$ from Drewien, R.C., pers. comm. and Case and Sanders 2009

$brood = 1.23$ from Drewien (2011).

$$PPM3 = \begin{pmatrix} \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & \alpha_6 & \alpha_7 & \alpha_8 & \alpha_9 \\ S_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & S_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & S_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & S_5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & S_6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & S_7 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & S_8 & S_9 \end{pmatrix}$$

where $\alpha_i = PropBreeding_i \times\ brood\ \times S_9^{8/12}/2$.

$PropBreeding$ = [0 0 0 0 0 0.154 0.333 0.600 0.500] from Tacha (1989).

$brood = 1.23$ from Drewien (2011).

$$PPM4 = \begin{pmatrix} \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & \alpha_6 & \alpha_7 & \alpha_8 & \alpha_9 \\ S_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & S_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & S_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & S_5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & S_6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & S_7 & 0 & \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & S_8 & S_9 \end{pmatrix}$$

where $\alpha_i = PropBreeding_i \times$ $brood$ $\times S_9^{8/12}/2$.

$PropBreeding$ = [0 0 0.05 0 0.10 0.20 0.40 0.50 1] from Tacha (1989).

$brood = 1.23$ from Drewien (2011).

Table A1. Single vital rate perturbations to sandhill crane population projection matrices (PPM) that stabilize long-term growth ($\lambda_\infty = 1$). The most sensitive survival by stage (S_{stage}) and per capita fecundity (F_{stage}) for each PPM are highlighted in grey.

Vital Rate	PPM1	PPM2	PPM3	PPM4
F or F9[a]	-0.06	-0.05	-0.27	-0.05
F8	NA[b]	NA	NA	NF[c]
F7	NA	NA	NA	NF
F6	NA	NA	NA	NF
F5	NA	NA	NA	NF
F4	NA	NA	NA	NF
S_1	-0.42	-0.34	-0.67	-0.36
S_2	-0.47	-0.38	-0.75	-0.41
S_3	-0.47	-0.38	-0.75	-0.41
S_4	-0.47	-0.38	-0.75	-0.41
S_5	-0.04	-0.38	-0.75	-0.41
S_6	NA	-0.38	-0.76	-0.42
S_7	NA	-0.38	-0.79	-0.42
S_8	NA	-0.38	-0.83	-0.44
S_9	NA	-0.03	-0.29	-0.04

[a] F applies only to PPM1 and F9 applies to PPM2-4.

[b] NA = Not Applicable.

[c] NF = Not Feasible.

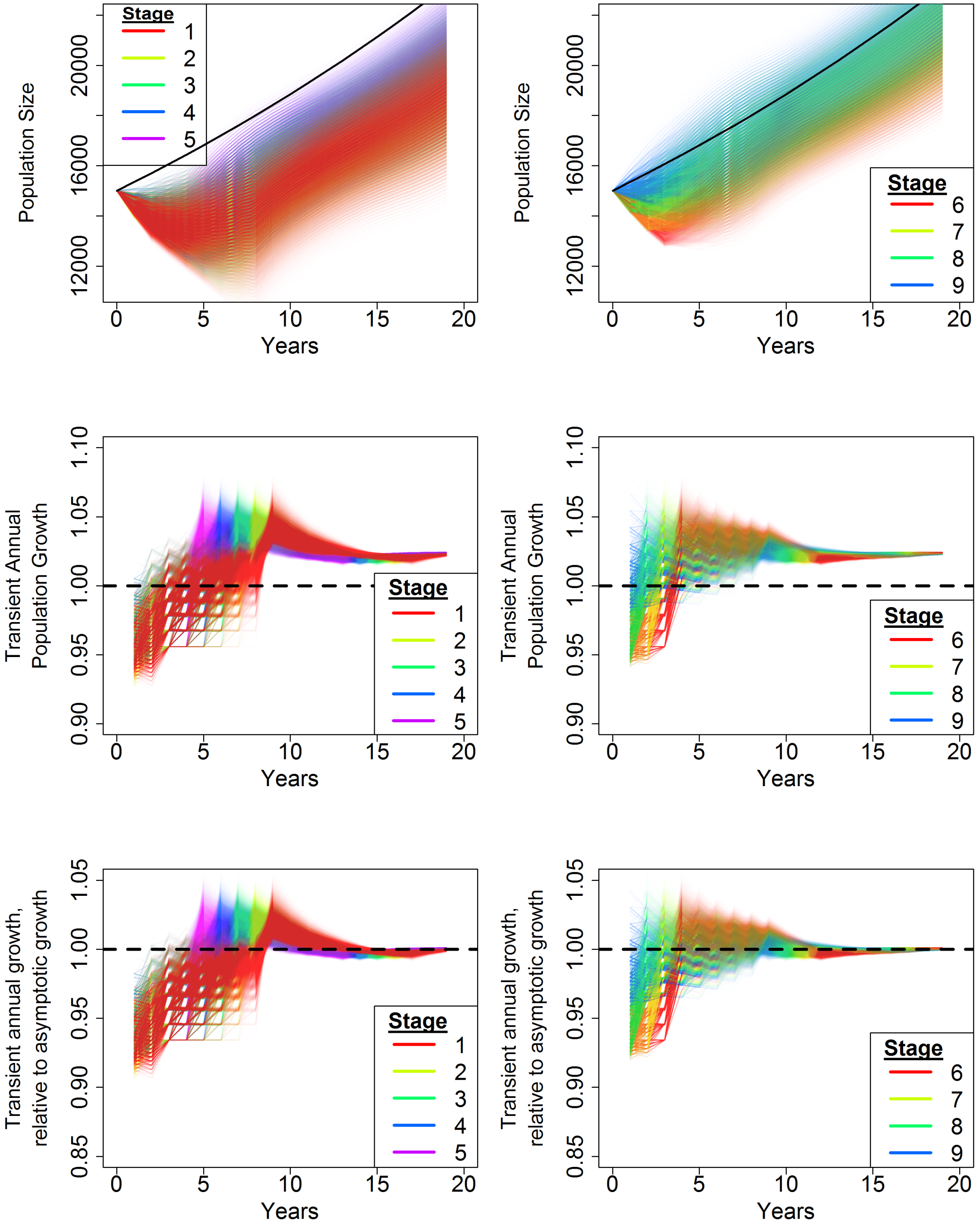

Figure A1: Projected population size over time, transient population growth, and transient population growth relative to λ_∞ across the complete set of initial population structures at intervals of 0.05 for PPM2. The numbers in the legend indicate the initial stage (1= juvenile, 9= oldest stage) with the majority of individuals. The solid black line in the top figure is population growth according to the stable stage distribution.

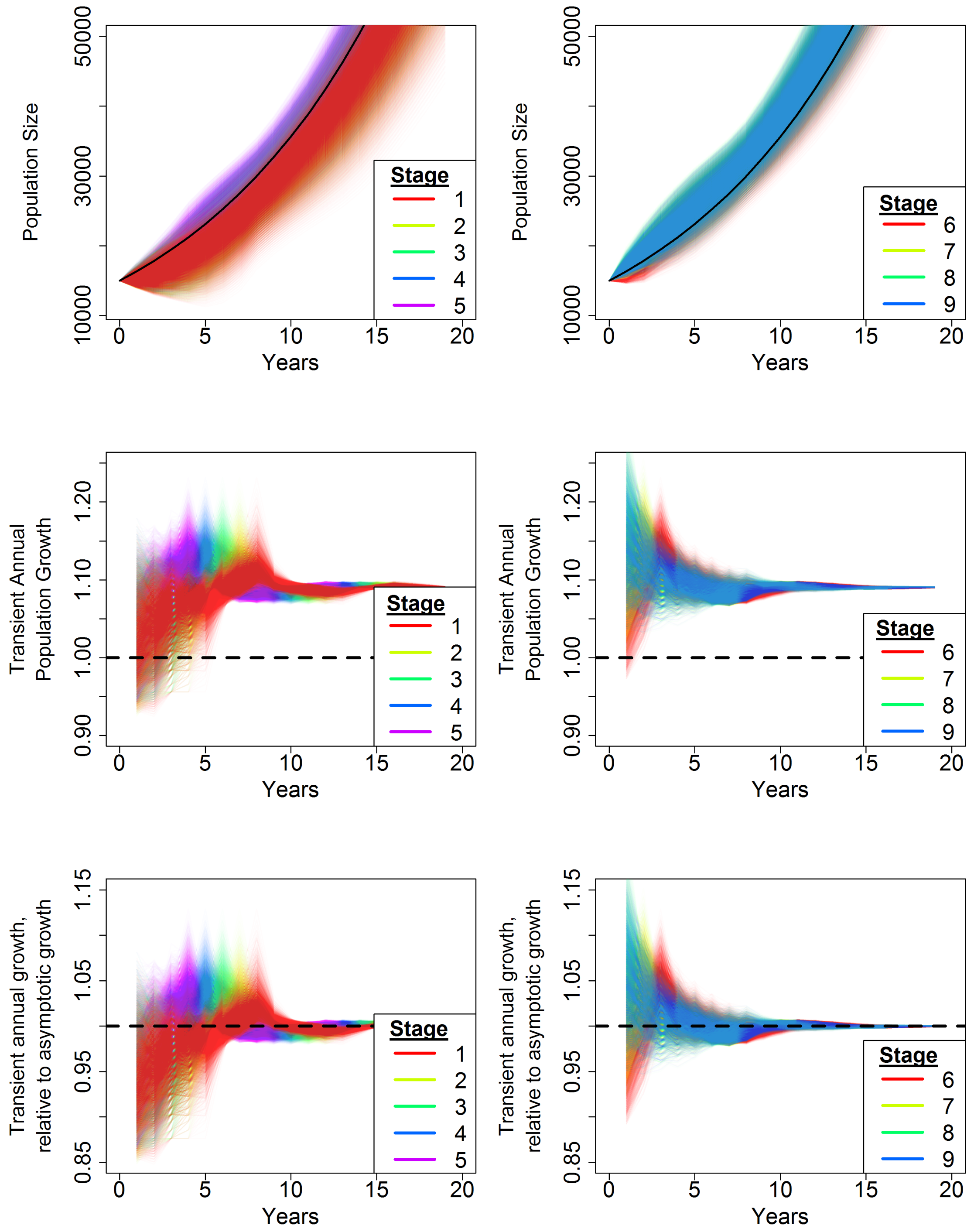

Figure A2: Projected population size over time, transient population growth, and transient population growth relative to λ_∞ across the complete set of initial population structures at intervals of 0.05 for PPM3. The numbers in the legend indicate the initial stage (1= juvenile, 9= oldest stage) with the majority of individuals. The solid black line in the top figure is population growth according to the stable stage distribution.

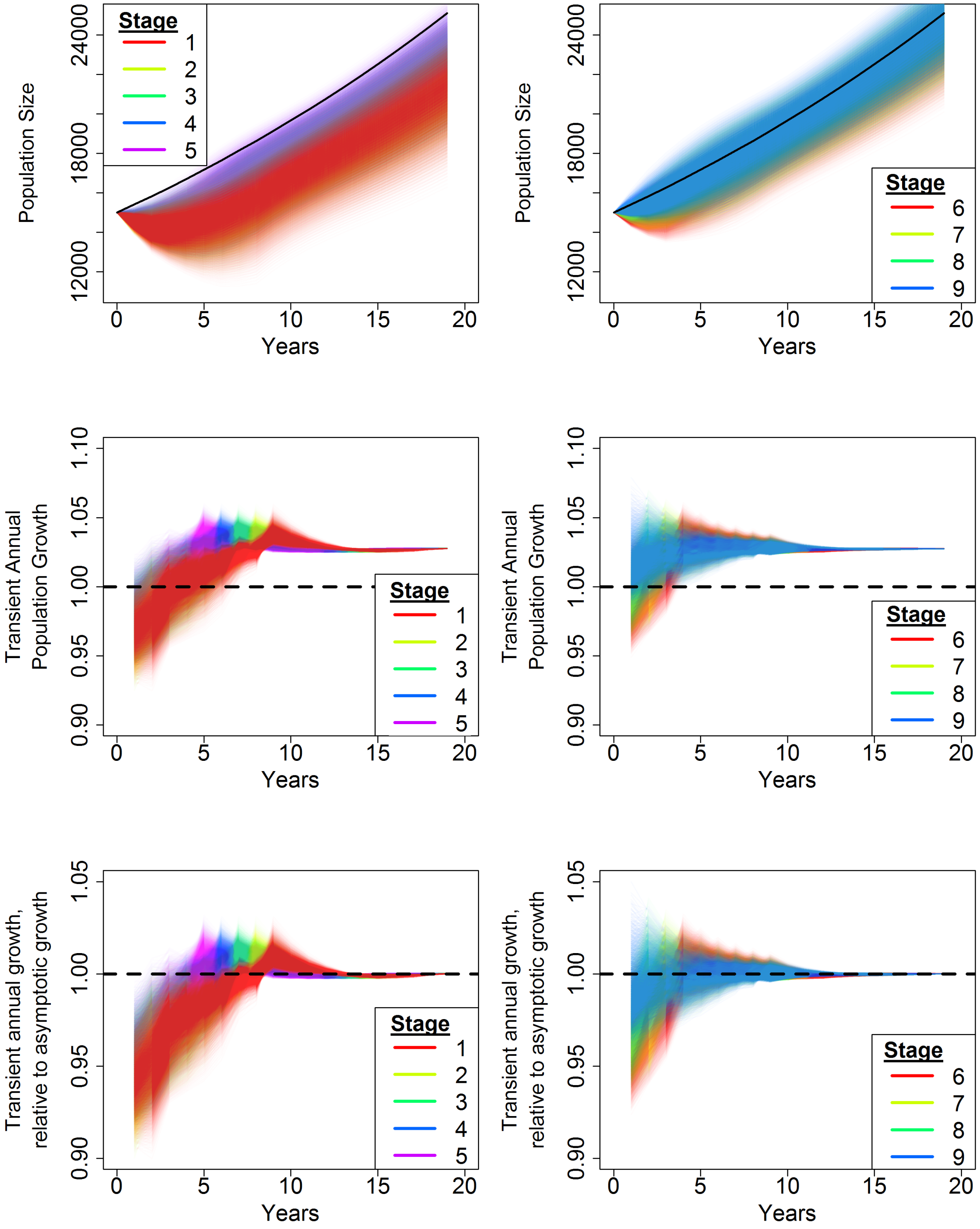

Figure A3: Projected population size over time, transient population growth, and transient population growth relative to λ_∞ across the complete set of initial population structures at intervals of 0.05 for PPM4. The numbers in the legend indicate the initial stage (1= juvenile, 9= oldest stage) with the majority of individuals. The solid black line in the top figure is population growth according to the stable stage distribution.

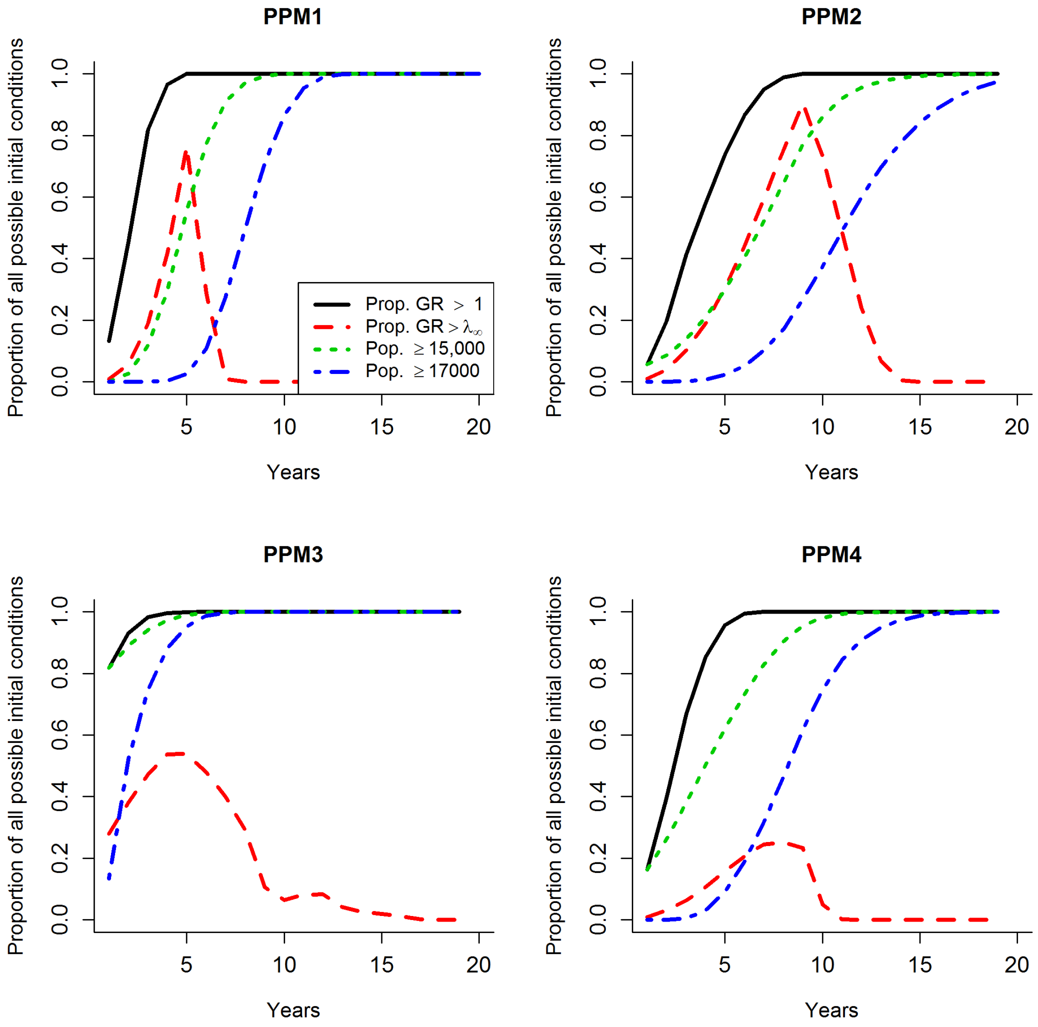

Figure A4: Proportion of projected populations initialized at all permutations of stage structures that: are growing (GR>1), are growing equal to or larger than the asymptotic growth rate, are harvestable (Pop. $\geq$ 15,000), and are above the lowest population objective (Pop. $\geq$ 17,000).

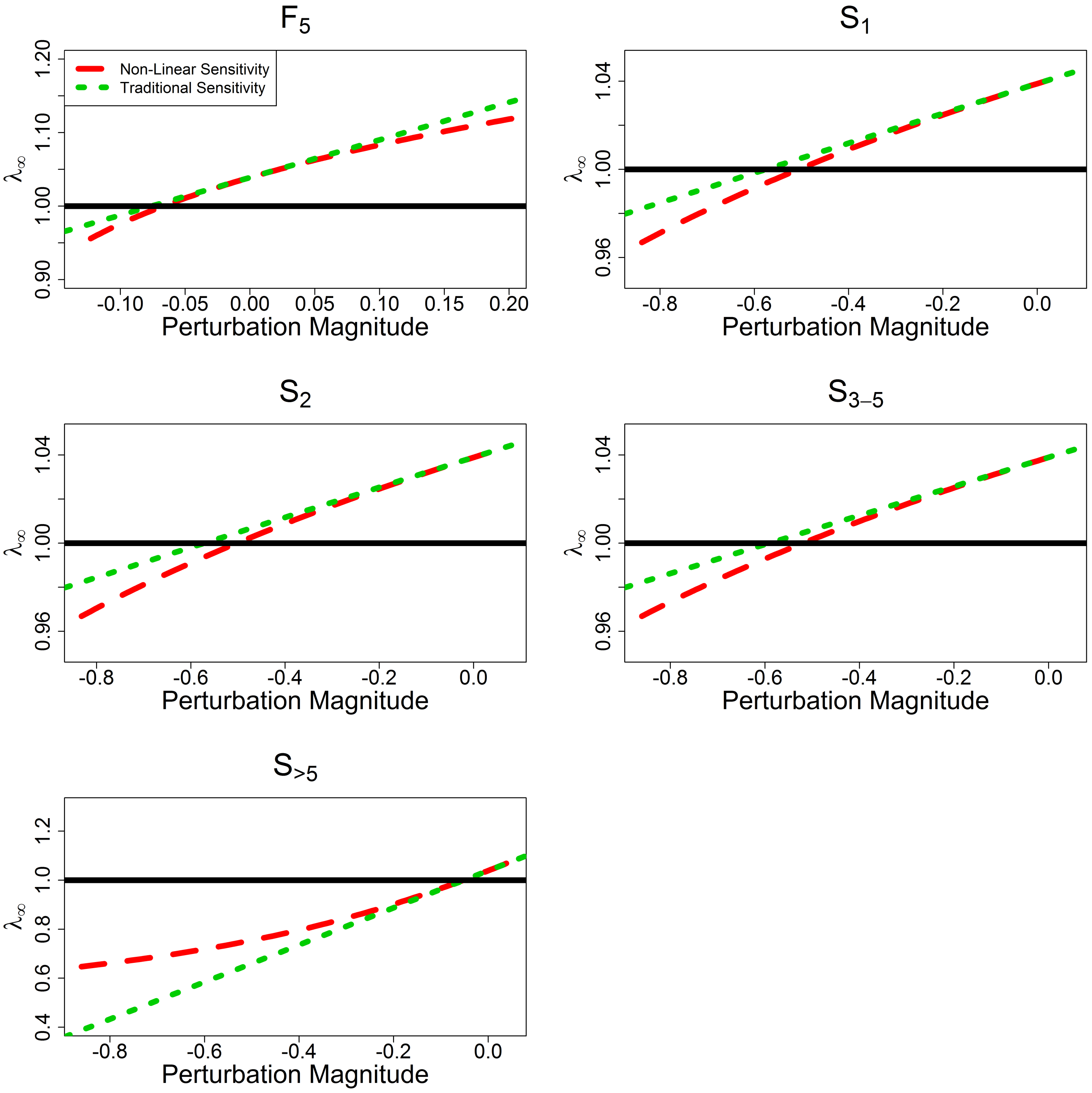

Figure A5: Traditional linear and non-linear (transfer function analysis) sensitivity analyses of vital rates of PPM1 and their affect on the asymptotic growth rate (λ_∞). Notice the y-axes are not the same.

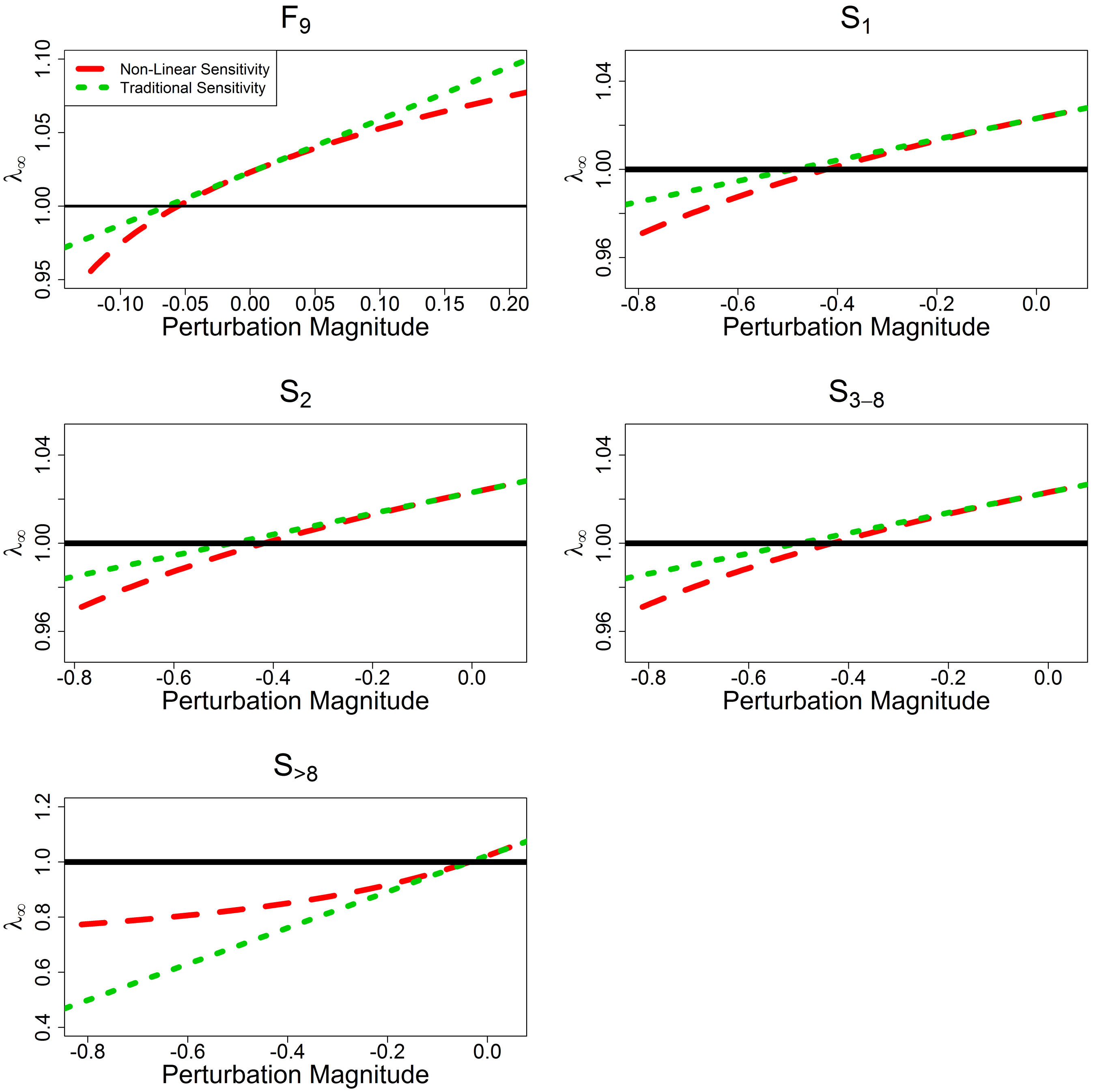

Figure A6: Traditional linear and non-linear (transfer function analysis) sensitivity analyses of vital rates of PPM2 and their affect on the asymptotic growth rate (λ_∞). Notice the y-axes are not scaled the same.

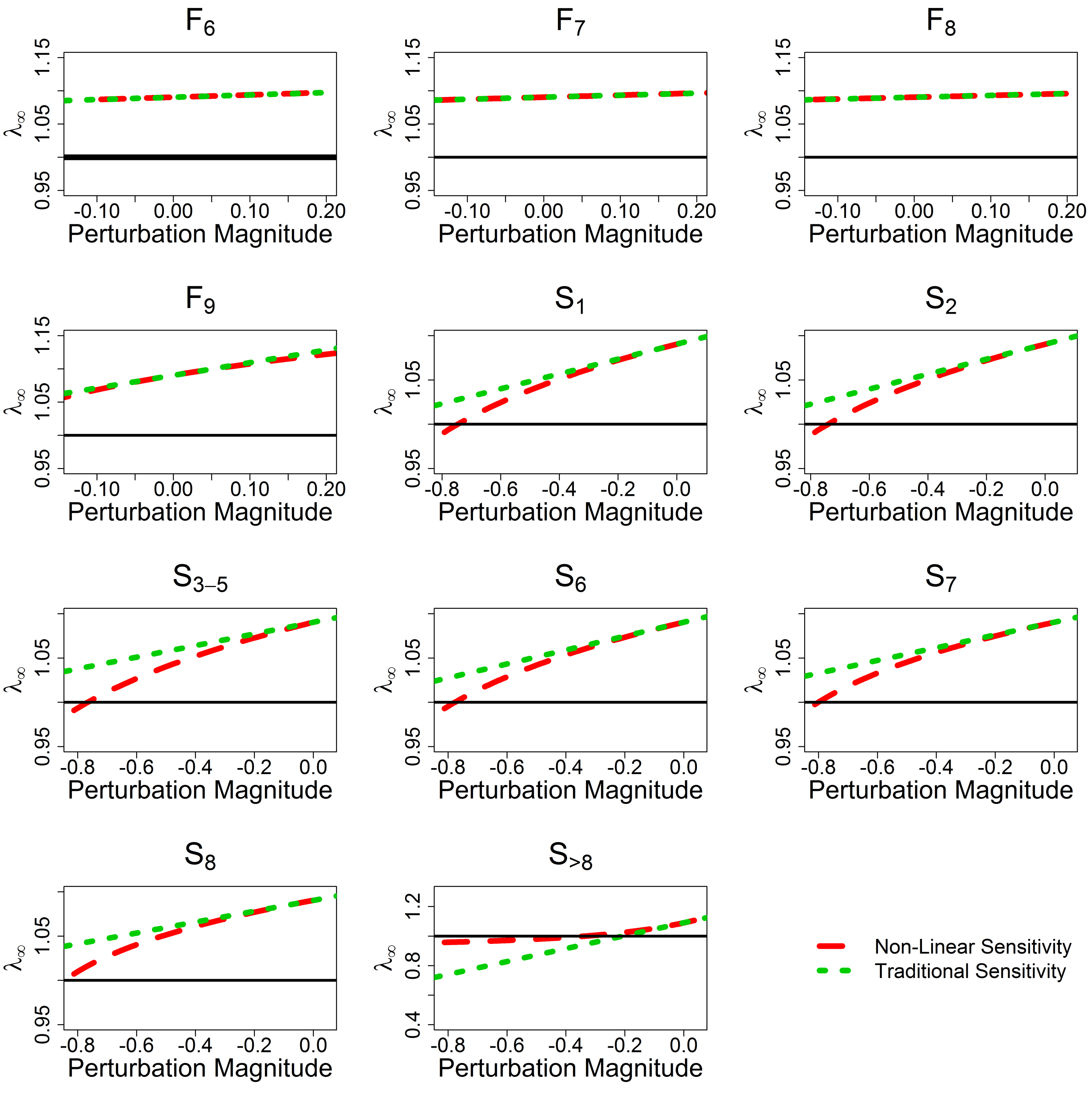

Figure A7: Traditional linear and non-linear (transfer function analysis) sensitivity analyses of vital rates of PPM3 and their affect on the asymptotic growth rate (λ_∞). Notice the y-axes are not scaled the same.

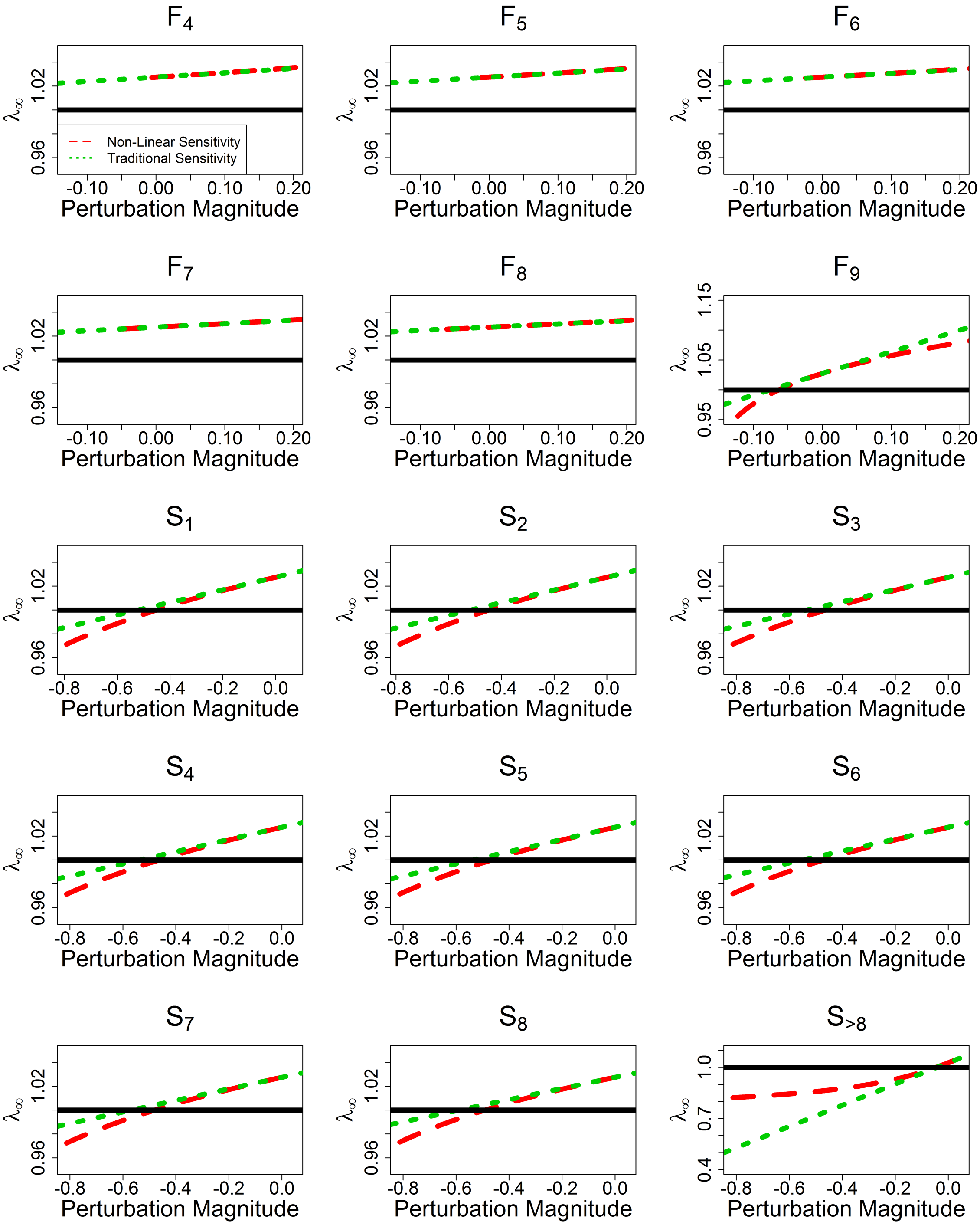

Figure A8: Traditional linear and non-linear (transfer function analysis) sensitivity analyses of vital rates of PPM4 and their affect on the asymptotic growth rate (λ_∞). Notice the y-axes are not scaled the same.

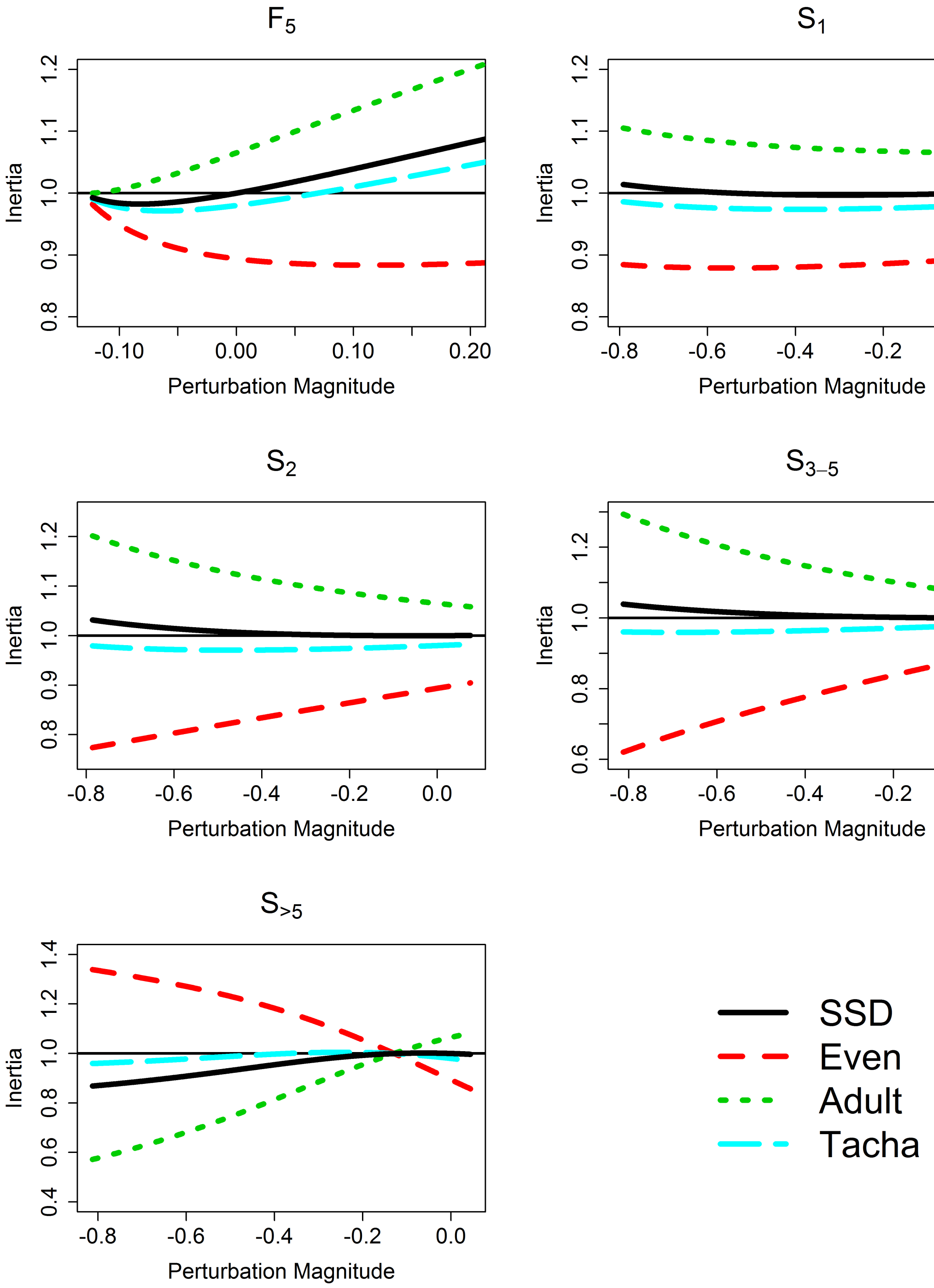

Figure A9: Non-linear perturbation analyses of vital rates of PPM1 and their effect on population inertia and initial stage distribution; Initial pre-perturbation stage distributions: "SSD" is stable stage distribution, "Even" is a stage distribution with individuals distributed evenly, "Adult" is a population with only individuals of the oldest stage, and "Tacha" assumes a stage distribution estimated from the mid-continent population of sandhill cranes (Tacha 1989).

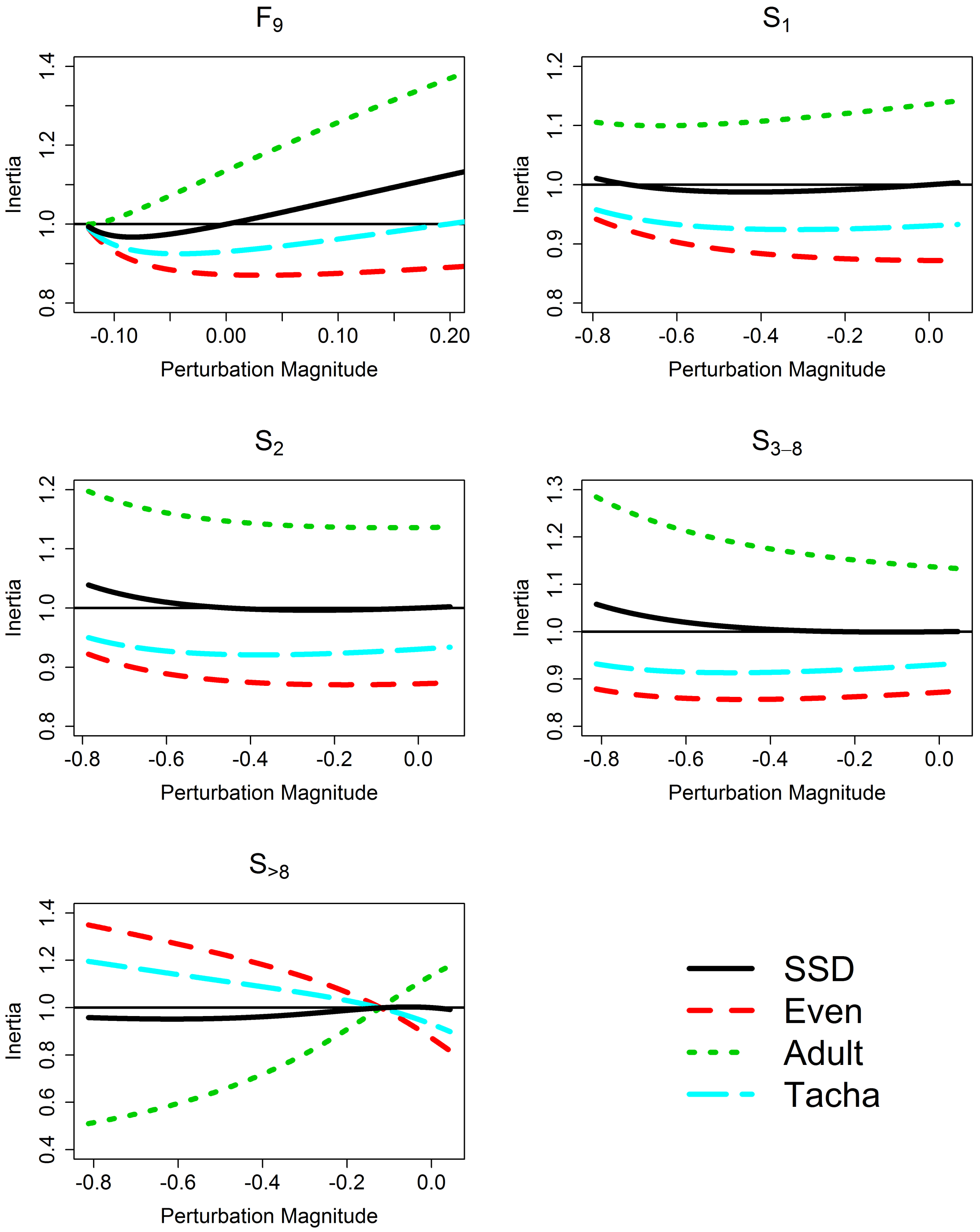

Figure A10: Non-linear perturbation analyses of vital rates of PPM2 and their effect on population inertia; comparison using different initial stage distributions: "SSD" is stable stage distribution, "Even" is a stage distribution with individuals distributed evenly, "Adult" is a population with only individuals of the oldest stage, and "Tacha" assumes a stage distribution estimated from the mid-continent population of sandhill cranes (Tacha 1989).

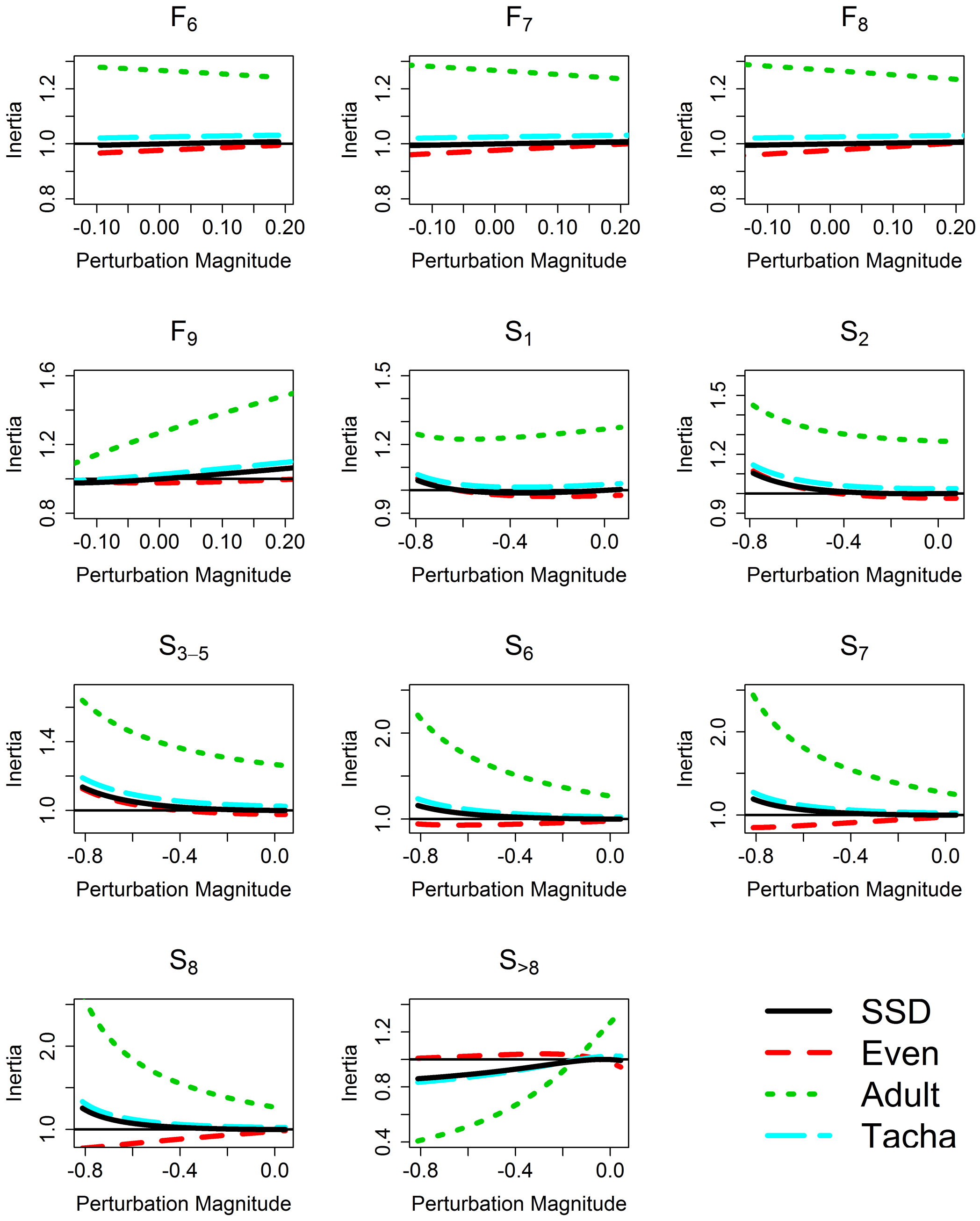

Figure A11: Non-linear perturbation analyses of vital rates of PPM3 and their effect on population inertia; comparison using different initial stage distributions: “SSD” is stable stage distribution, “Even” is a stage distribution with individuals distributed evenly, “Adult” is a population with only individuals of the oldest stage, and “Tacha” assumes a stage distribution estimated from the mid-continent population of sandhill cranes (Tacha 1989).

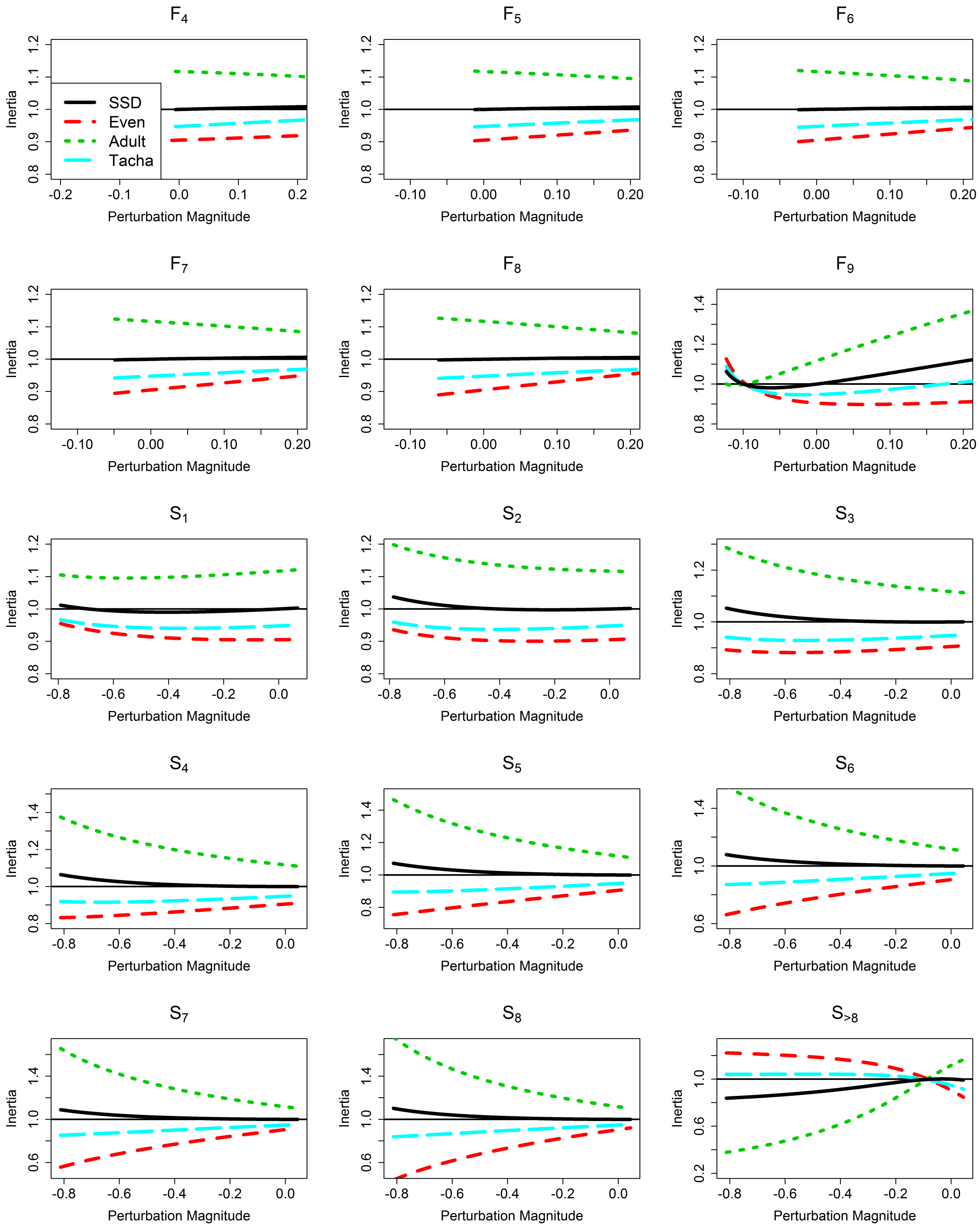

Figure A12: Non-linear perturbation analyses of vital rates of PPM4 and their effect on population inertia; comparison using different initial stage distributions: "SSD" is stable stage distribution, "Even" is a stage distribution with individuals distributed evenly, "Adult" is a population with only individuals of the oldest stage, and "Tacha" assumes a stage distribution estimated from the mid-continent population of sandhill cranes (Tacha 1989).

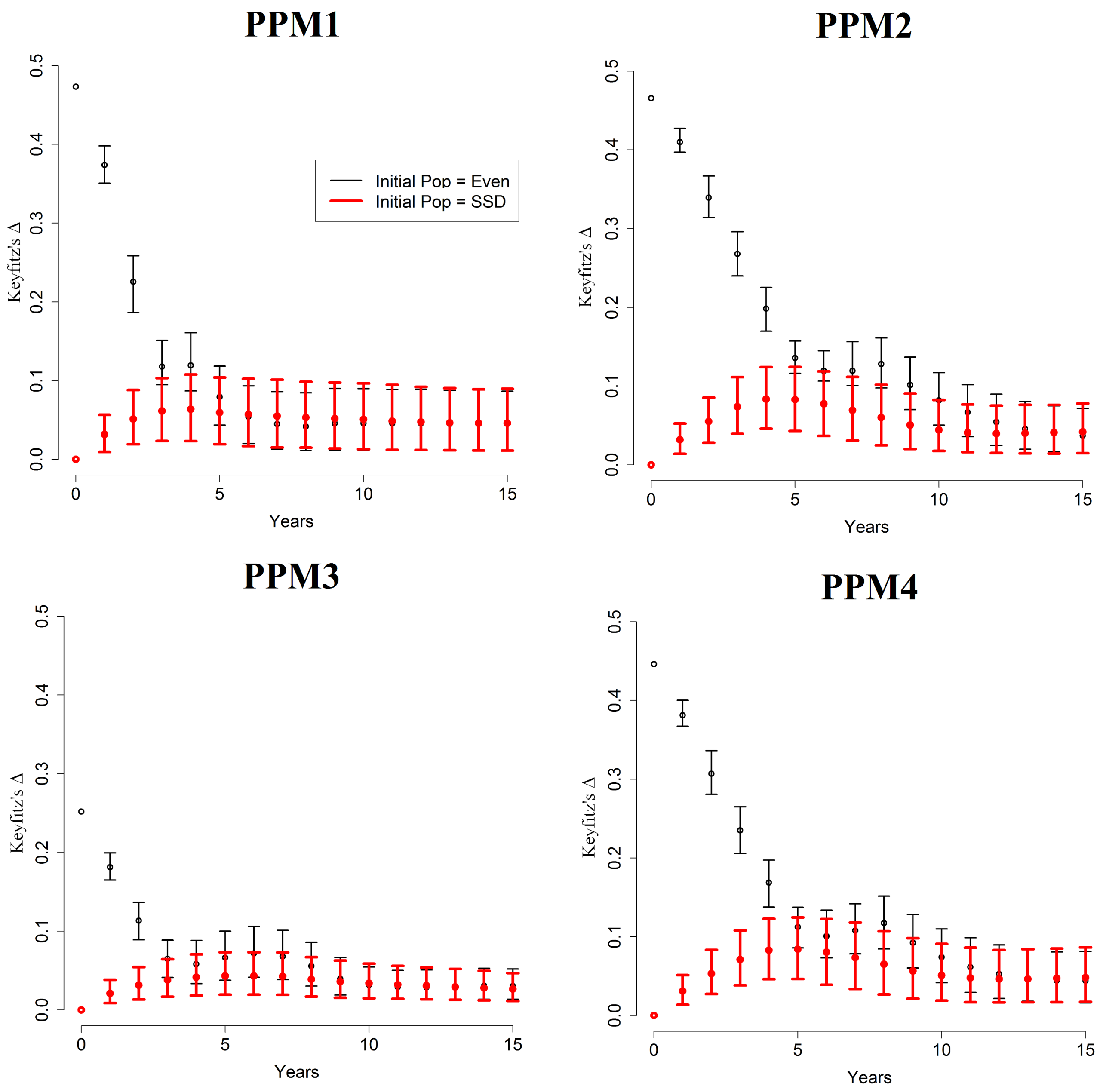

Figure A13: The Keyfitz's Δ between the stable stage distribution (SSD) of non-harvested and stochastically harvested populations, initialized at either the SSD of the non-harvested population or an even stage distribution; zero indicates no difference between two population stage structures and 1 indicates the maximum difference. Harvest effected the stage structure evenly, on average.

References

Case, D., and S. Sanders. 2009. Priority information needs for sandhill cranes: a funding strategy. Tech. rep., U.S. Fish and Wildlife Service.

Drewien, R.C. 2011. Recruitment survey of the rocky mountain population of greater sandhill cranes. Unpublished Report to U.S. Fish and Wildlife Service, Migratory Bird Office, Region 6.

Tacha, T.C., and D.E. Haley, and P.A. Vohs. 1989. Age of sexual maturity of sandhill cranes from mid-continental North America. Journal of Wildlife Management, **53**, 43–46.